Project Summary

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Reservoir Bottom Effects on Hydrodynamic Loads for Concrete Dams

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Problem Statement: Commonly used finite-element analysis techniques in the time domain do not take into account the absorption and/or transmission of hydrodynamic pressure waves by/through the sediments and the foundation rock that form the reservoir boundary. The assumption of a rigid, i.e., non-absorbing, reservoir boundary may lead to an unrealistically large estimation of the earthquake response of the reservoir-dam-foundation system.

Objectives: (1) Develop an analytical tool to quantify the absorption/transmission effect of the reservoir bottom and dam foundation in the time domain (thereby allowing the representation of the nonlinear behavior of the system), and (2) Develop practical procedures to identify the site-specific and spatially-varying parameters entering the formulation to realistically compute the response of dam-impounded water systems subjected to large earthquakes.

Description: Conduct geophysical field measurements at dam sites to quantify material properties of reservoir bottom rock. Conduct physical experiments to investigate the effect of reservoir and dam foundation stiffness and geometry, reservoir pool geometry, and dam geometry on the earthquake response of the reservoir-dam-foundation system. Develop numerical procedures to analyze the field and physical experimental results. Develop computational mathematical models to represent the effective earthquake forces on the upstream face of a given concrete dam impounding water. Develop practical procedures and guidance for earthquake analysis of reservoir-dam-foundation systems including bottom rock absorption/transmission effects.

Intended User: Corps Districts and Divisions will use the products in practical seismic analysis and design of concrete dams. The research will provide procedural guidance as to the proper evaluation in the field of parameters needed to realistically predict seismic response of concrete dams, including bottom absorption of energy, and will provide a computer program to construct realistic hydrodynamic force spectra for analysis of existing or design of new dams at a given site when subjected to a selected input ground motion accelerogram.

Figure 1. Pine Flat Dam

Products: An initial phase of the experimental objective of the project was completed. Field measurements of characteristic coefficients of reflection were attempted at seven prototype dams within the continental U.S. The report on this activity was published and is available. A final phase of the experimental objective of the project was also completed. Field measurements of the acoustic impedance of the reservoir bottom rock were conducted at Pine Flat Dam in central California. This three-dimensional sampling exercise using a waterborne seismic surveying technique provides the data to infer the statistical characterization of the coefficient of reflection field in the region adjacent to the upstream face of the dam. The report on this activity was published and is available. On the computational objective of the project, the following accomplishments are reported at this time: (1) Development of a time-domain model for the hydrodynamic pressure field on the upstream vertical face of a given rigid dam subjected to a given horizontal ground motion accelerogram (Model includes bottom absorption of energy at an elastic bottom), (2) Implementation of a MathCad script for the thorough automatic calculation of the time-history of typical parameters of response, (3) Implementation of a MathConnex system for the construction of design response spectra for the magnitude and location of the resultant hydrodynamic force on the dam, and (4) Extension of the mathematical model above to include the simultaneous response of a flexible dam to both the horizontal and the vertical components of ground motion.

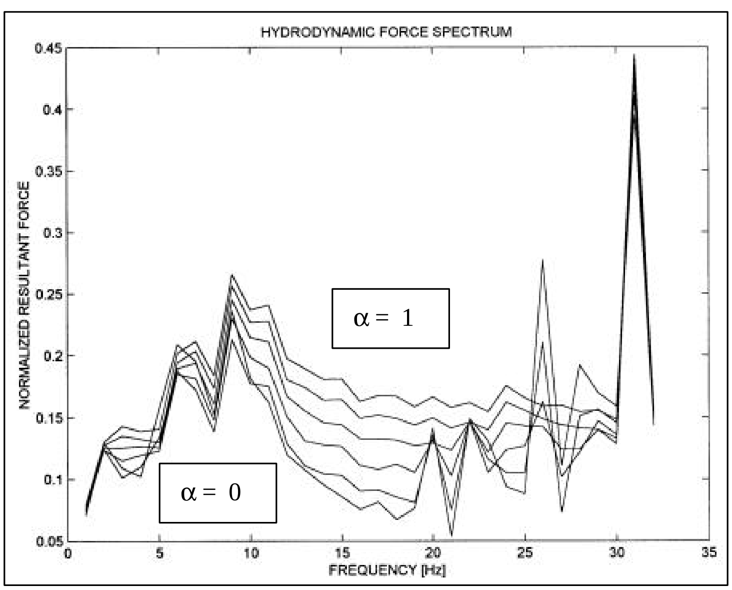

Figure 2. A typical family of hydrodynamic force response spectra